

1 **WHAT IS CLAIMED IS:**

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- 3 1. An apparatus for converting hydrocarbon fuel into a hydrogen rich gas comprising:
- 4 a manifold for mixing the hydrocarbon fuel with an oxygen containing gas to give a
- 5 fuel mixture;
- 6 an autothermal reactor including a catalyst for reacting the fuel mixture under
- 7 autothermal reforming conditions to give a hydrogen containing gaseous mixture;
- 8 a water gas shift reactor including a catalyst for reacting the hydrogen containing
- 9 gaseous mixture under water gas shift reaction conditions to give an intermediate
- 10 hydrogen containing gaseous mixture with a substantially reduced carbon
- 11 monoxide content; and
- 12 a selective oxidation reactor including a catalyst for reacting the intermediate
- 13 hydrogen containing gaseous mixture under selective oxidation reaction
- 14 conditions to produce the hydrogen rich gas.
- 15
- 16 2. The apparatus according to claim 1, further comprising a heat exchanger for heating
- 17 the hydrocarbon fuel into a heated hydrocarbon fuel, wherein the heated hydrocarbon
- 18 fuel becomes the hydrocarbon fuel feed to the manifold.
- 19
- 20 3. The apparatus according to claim 2, further comprising a desulfurization reactor
- 21 including a catalyst for reacting the heated hydrocarbon fuel under desulfurization
- 22 conditions to produce a substantially desulfurized hydrocarbon fuel, wherein the
- 23 substantially desulfurized hydrocarbon fuel becomes the hydrocarbon fuel feed to the
- 24 manifold.
- 25
- 26 4. The apparatus according to claim 1, further comprising a heat exchanger for heating
- 27 the fuel mixture to produce a heated fuel mixture, wherein the heated fuel mixture
- 28 becomes the fuel mixture feed to the autothermal reactor.
- 29
- 30 5. The apparatus according to claim 4, further comprising a desulfurization reactor
- 31 including a catalyst for reacting the hydrogen containing gaseous mixture under

- 1 desulfurization conditions to produce a substantially desulfurized hydrogen
- 2 containing gaseous mixture, wherein the substantially desulfurized hydrogen
- 3 containing gaseous mixture becomes the hydrogen containing gaseous mixture feed to
- 4 the water gas shift reactor.
- 5
- 6 6. The apparatus according to claim 1, wherein the hydrocarbon fuel is selected from the
- 7 group consisting of natural gas, methane, ethane, propane, butane, liquefied
- 8 petroleum gas, naphtha, gasoline, kerosene, diesel, methanol, ethanol, propanol, and
- 9 combinations thereof.
- 10
- 11 7. The apparatus according to claim 1, wherein the hydrogen rich gas contains less than
- 12 50 ppm of carbon monoxide.
- 13
- 14 8. The apparatus according to claim 1, further comprising an anode tail gas oxidizer
- 15 including a catalyst for reacting the unconverted hydrogen from a fuel cell under
- 16 oxidation conditions to create a hot anode tail gas oxidizer effluent.
- 17
- 18 9. The apparatus according to claim 8, wherein the hot anode tail gas oxidizer effluent is
- 19 heat integrated with the apparatus.
- 20
- 21 10. An apparatus for converting hydrocarbon fuel into a hydrogen rich gas comprising:
- 22 a first heat exchanger for heating the hydrocarbon fuel to produce a heated
- 23 hydrocarbon fuel;
- 24 a first desulfurization reactor for reacting the heated hydrocarbon fuel to produce a
- 25 substantially desulfurized hydrocarbon fuel;
- 26 a manifold for mixing the substantially desulfurized hydrocarbon fuel with an oxygen
- 27 containing gas to produce a fuel mixture;
- 28 a second heat exchanger for heating the fuel mixture to produce a heated fuel mixture;
- 29 an autothermal reactor including a catalyst for reacting the heated fuel mixture to
- 30 produce a first hydrogen containing gaseous mixture;

- 1 a second desulfurization reactor for reacting the first hydrogen containing gaseous
- 2 mixture to produce a second hydrogen containing gaseous mixture that is
- 3 substantially desulfurized;
- 4 a water gas shift reactor for reacting the second hydrogen containing gaseous mixture
- 5 to produce a third hydrogen containing gaseous mixture with a substantially
- 6 decreased carbon monoxide content; and
- 7 a selective oxidation reactor for reacting the third hydrogen containing gaseous
- 8 mixture to produce the hydrogen rich gas; and
- 9
- 10 11. The apparatus according to claim 10, wherein the hydrocarbon fuel is selected from
- 11 the group consisting of natural gas, methane, ethane, propane, butane, liquefied
- 12 petroleum gas, naphtha, gasoline, kerosene, diesel, methanol, ethanol, propanol, and
- 13 combinations thereof.
- 14
- 15 12. The apparatus according to claim 10, wherein the hydrogen rich gas contains less than
- 16 50 ppm of carbon monoxide.
- 17
- 18 13. The apparatus according to claim 10, further comprising an anode tail gas oxidizer
- 19 including a catalyst for reacting the unconverted hydrogen from a fuel cell under
- 20 oxidation conditions to create a hot anode tail gas oxidizer effluent.
- 21
- 22 14. The apparatus according to claim 13, wherein the hot anode tail gas oxidizer effluent
- 23 is heat integrated with the apparatus.
- 24
- 25 15. A method for converting hydrocarbon fuel into a hydrogen rich gas, comprising:
- 26 mixing the hydrocarbon fuel with an oxygen containing gas to produce a fuel
- 27 mixture;
- 28 reacting the fuel mixture in the presence of a catalyst under autothermal reforming
- 29 reaction conditions to produce a hydrogen containing gaseous mixture;
- 30 reacting the hydrogen containing gaseous mixture in the presence of a catalyst under
- 31 water gas shift reaction conditions to produce an intermediate hydrogen

- 1 containing gaseous mixture with a substantially reduced carbon monoxide
- 2 content; and
- 3 reacting the intermediate hydrogen containing gaseous mixture in the presence of a
- 4 catalyst under selective oxidation conditions to produce the hydrogen rich gas.
- 5
- 6 16. The method according to claim 15 further comprising heating the hydrocarbon fuel to
- 7 produce a heated hydrocarbon fuel, wherein the heated hydrocarbon fuel becomes the
- 8 hydrocarbon fuel feed to the mixing step.
- 9
- 10 17. The method according to claim 16 further comprising reacting the heated
- 11 hydrocarbon fuel in the presence of a catalyst under desulfurization conditions to
- 12 produce a substantially desulfurized hydrocarbon fuel, wherein the substantially
- 13 desulfurized hydrocarbon fuel becomes the hydrocarbon fuel feed to the mixing step
- 14 in a manifold.
- 15
- 16 18. The method according to claim 15, further comprising heating the fuel mixture to
- 17 produce a heated fuel mixture, wherein the heated fuel mixture becomes the fuel
- 18 mixture feed to the first reaction step.
- 19
- 20 19. The method according to claim 15, further comprising reacting the hydrogen
- 21 containing gaseous mixture in the presence of a catalyst under desulfurization
- 22 reaction conditions to produce a substantially desulfurized hydrogen containing
- 23 gaseous mixture, wherein the substantially desulfurized hydrogen containing gaseous
- 24 mixture becomes the hydrogen containing gaseous mixture feed to the second
- 25 reaction step.
- 26
- 27 20. The method according to claim 15, wherein the hydrocarbon fuel is selected from the
- 28 group consisting of natural gas, methane, ethane, propane, butane, liquefied
- 29 petroleum gas, naphtha, gasoline, kerosene, diesel, methanol, ethanol, propanol, and
- 30 combinations thereof.
- 31

- 1 21. The method according to claim 15, wherein the hydrogen rich gas contains less than
2 50 ppm of carbon monoxide.
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- 4 22. The method according to claim 15, further comprising reacting anode tail gas from a
5 fuel cell in the presence of a catalyst under oxidation conditions to produce a hot
6 anode tail gas oxidizer effluent.
7
- 8 23. The method according to claim 22, wherein the hot anode tail gas oxidizer effluent
9 preheats the hydrocarbon fuel.
10
- 11 24. A method for converting hydrocarbon fuel into a hydrogen rich gas, comprising:
12 heating the hydrocarbon fuel to produce a heated hydrocarbon fuel;
13 reacting the heated hydrocarbon fuel in the presence of a catalyst under
14 desulfurization conditions to produce a substantially desulfurized hydrocarbon;
15 mixing the substantially desulfurized hydrocarbon with an oxygen containing gas to
16 produce a fuel mixture;
17 heating the fuel mixture to produce a heated fuel mixture;
18 reacting the heated fuel mixture in the presence of a catalyst under auto thermal
19 reforming conditions to produce a first hydrogen containing gaseous mixture;
20 reacting the first hydrogen containing gaseous mixture in the presence of a catalyst
21 under desulfurization conditions to produce a second hydrogen containing
22 gaseous mixture that is substantially desulfurized;
23 reacting the second hydrogen containing gaseous mixture with a catalyst under water
24 gas shift reaction conditions to produce a third hydrogen containing gaseous
25 mixture with a substantially reduced carbon monoxide content; and
26 reacting the third hydrogen containing gaseous mixture in the presence of a catalyst
27 under selective oxidation reaction conditions of to produce the hydrogen rich gas.
28
- 29 25. The method according to claim 24, wherein the hydrocarbon fuel is selected from the
30 group consisting of natural gas, methane, ethane, propane, butane, liquefied

1 petroleum gas, naphtha, gasoline, kerosene, diesel, methanol, ethanol, propanol, and
2 combinations thereof.

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4 26. The method according to claim 24, wherein the hydrogen rich gas contains less than
5 50 ppm of carbon monoxide.

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7 27. The method according to claim 24, further comprising reacting anode tail gas from a
8 fuel cell in the presence of a catalyst under oxidation conditions to produce a hot
9 anode tail gas oxidizer effluent.

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11 28. The method according to claim 27, wherein the hot anode tail gas oxidizer effluent
12 preheats the hydrocarbon fuel.

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